2007

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The Professional Animal Scientist 23 (2007):467–475

Effects of Graded Levels of Sorghum Wet Distiller's Grains and Degraded Intake Protein Supply on Performance and Carcass Characteristics of Feedlot Cattle Fed Steam-Flaked Corn-Based Diets[1]

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ABSTRACT

Two experiments evaluated different levels of sorghum wet distiller's grains plus solubles (SWDG) and effects of increasing the degraded intake protein (DIP) concentration in diets containing SWDG on performance and carcass characteristics of feedlot cattle. In Exp. 1, 200 beef steers (average BW = 404 kg) were fed increasing levels of SWDG (0, 5, 10, and 15% of DM) and one level of corn wet distiller's grains plus solubles (10% of DM), which replaced steam-flaked corn in a high-concentrate diet. Final BW (P = 0.04) and overall ADG (P = 0.01) decreased linearly with increasing levels of SWDG. Increasing SWDG decreased overall G:F (P = 0.01), hot carcass weight (P < 0.01), and LM area (P < 0.01). No differences were observed in overall DMI (P = 0.15) or other carcass characteristics ($P \geq 0.09$). Neither DMI nor G:F differed between corn wet distiller's grains plus solubles and SWDG when fed as 10% of the dietary DM. In Exp. 2, 200 steers (average BW = 369 kg) were either fed a control diet without SWDG (8.4% DIP) or three 10% SWDG diets with no urea added or urea added at either 50% or 100% of the difference in the DIP concentration between the diet with no urea added and control diets. Final BW (P = 0.03), overall ADG (P = 0.04), and overall G:F (P = 0.05) were greater for cattle fed the control diet. A linear decrease was observed in overall DMI with increasing DIP (P = 0.02). Likewise, overall ADG decreased with increasing DIP (P = 0.08). Cattle fed the control diet had greater hot carcass weight (P = 0.03), fat thickness (P = 0.02), and yield grade (P = 0.01) than the average of those fed the 3 SWDG diets. Results from both experiments suggest decreased performance and carcass value with increasing levels of SWDG alone or combined with additional DIP. At 10% of the dietary DM, corn and sorghum wet distiller's grains resulted in similar ADG and G:F.

Key words: cattle, feedlot, sorghum, wet distiller's grains

INTRODUCTION

The yearly production capacity of ethanol in the United States was expected to be more than 22.7×10^9 L by the end of 2006 (Loy et al., 2005). Most of the coproducts of this production can be fed to ruminant animals.

[1]This experiment was supported, in part, by a cooperative agreement between the USDA-ARS and Texas Tech University. The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-ARS or Texas Tech University.
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Table 1. Composition and analyzed nutrient content (DM basis) of diets containing increasing levels of sorghum wet distiller's grains (Exp. 1)

	Treatment diets[1]				
Item	0	S5%	S10%	S15%	C10%
Ingredient					
Steam-flaked corn	75.40	73.90	70.67	65.73	71.04
Cottonseed hulls	7.62	7.59	7.56	7.53	7.60
Cottonseed meal	5.86	1.97	—	—	—
Urea	1.01	1.01	0.77	0.25	0.81
Limestone	0.26	0.35	0.52	0.81	0.53
Fat	3.06	3.05	3.04	3.02	3.06
Molasses	4.25	4.23	4.22	4.19	4.24
Supplement[2,3]	2.54	2.53	2.52	2.50	2.52
Sorghum wet distiller's grain	—	5.37	10.70	15.97	—
Corn wet distiller's grain	—	—	—	—	10.20
Analyzed composition					
DM, %	81.19	76.27	72.57	70.54	71.09
CP, %	11.71	11.82	12.26	12.29	12.17
ADF, %	9.06	9.08	12.07	12.99	10.51
Ash, %	2.43	2.44	2.69	3.35	2.70
Ca, %	0.60	0.64	0.71	0.82	0.71
P, %	0.32	0.34	0.38	0.44	0.38
DIP, % of DM[1]	8.09	7.52	6.84	5.75	6.95

[1]Treatments were as follows: 0 = 90% concentrate control diet; S5% = 5% (DM basis) added sorghum wet distiller's grains; S10% = 10% (DM basis) added sorghum wet distiller's grains; S15% = 15% (DM basis) added sorghum wet distiller's grains; and C10% = 10% (DM basis) added wet corn distiller's grains. The DIP values are calculated from NRC (1996).

[2]Supplement for the control diet contained (DM basis) 23.37% cottonseed meal; 0.500% Endox (antioxidant; Kemin Industries, Des Moines, IA); 42.11% limestone; 1.036% dicalcium phosphate; 8.000% potassium chloride; 3.559% magnesium oxide; 6.667% ammonium sulfate; 12.000% salt; 0.0017% cobalt carbonate; 0.157% copper sulfate; 0.133% iron sulfate; 0.0025% ethylenediamine dihydroiodide; 0.267% manganese oxide; 0.100% selenium premix (0.2% Se); 0.845% zinc sulfate; 0.0079% vitamin A (1,000,000 IU/g); 0.126% vitamin E (500 IU/g); 0.675% Rumensin (176.4 mg/kg; Elanco Animal Health, Indianapolis, IN); and 0.45% Tylan (88.2 mg/kg; Elanco Animal Health). Concentrations in parentheses are expressed on a 90% DM basis.

[3]Supplement for the distiller's grains diets contained (DM basis) 30.03% ground corn; 0.500% Endox; 42.11% limestone; 1.036% dicalcium phosphate; 8.000% potassium chloride; 3.559% magnesium oxide; 12.000% salt; 0.0017% cobalt carbonate; 0.157% copper sulfate; 0.133% iron sulfate; 0.0025% ethylenediamine dihydroiodide; 0.267% manganese oxide; 0.100% selenium premix (0.2% Se); 0.845% zinc sulfate; 0.0079% vitamin A (1,000,000 IU/g); 0.126% vitamin E (500 IU/g); 0.675% Rumensin (176.4 mg/kg); and 0.45% Tylan (88.2 mg/kg). Concentrations in parentheses are expressed on a 90% DM basis.

One of these coproducts, wet distiller's grains (**WDG**), provides a source of both energy and CP in finishing diets for beef cattle. Wet distiller's grains contain large portions of undegraded intake protein (**UIP**) compared with other feedstuffs. Most finishing diets in the High Plains region include steam-flaked corn (**SFC**) as the grain source. Because SFC is such a readily available source of starch, it is quickly and extensively fermented in the rumen. This extensive starch fermentation yields high microbial protein production, resulting in an increased need for degraded intake protein (**DIP**) to maintain microbial synthesis. Thus, in diets in which WDG is substituted for SFC, UIP is increased at the expense of DIP, and this exchange of UIP for DIP might result in decreased animal performance. Two experiments were designed to evaluate the feeding value of sorghum WDG (**SWDG**) in SFC-based diets. The objectives of these studies were 1) to evaluate increasing levels of SWDG on performance and carcass characteristics of feedlot cattle; and 2) to determine whether additional DIP, added in the form of urea, was necessary to optimize performance by cattle fed diets containing SWDG.

MATERIALS AND METHODS

Experiment 1

Two hundred steers (initial BW = 404 ± 7.34 kg) were selected from a larger group (received October 2003 at the Texas Tech University Burnett Center at New Deal, TX) and used in a randomized complete block design with 5 dietary treatments. Steers were processed on arrival, which included assignment of a uniquely numbered ear tag, vaccination for infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza-3, and bovine respiratory syncitial virus with Titanium 5 (Agri-Labs, St. Joseph, MO) and Vision 7 with SPUR (*Clostridium chauvoei-septicum-novyi-sordelli-perfringens* Types C and D bacterin-toxoid; Intervet, Millsboro DE), and treatment for internal and external parasites with Cydectin (Ft. Dodge Animal Health, Overland Park, KS). Approximately 30 d before the beginning of the experiment, a BW measurement was obtained and used to assign the steers to 8 weight blocks. Five treatments were assigned randomly to pens (5 steers per pen) within these blocks, and the steers were adapted to a 90% concentrate diet. Steers were then weighed and

Table 2. Composition and analyzed nutrient content (DM basis) of diets containing increasing concentrations of degraded intake protein (Exp. 2)

Item	Control	DIP restored,[1] % 0	50	100
Ingredient				
Steam-flaked corn	74.50	70.64	70.44	70.23
Cottonseed hulls	4.98	5.00	5.00	5.00
Alfalfa hay, ground	4.93	4.96	4.96	4.95
Urea	1.00	0.68	0.89	1.09
Cottonseed meal	5.19	—	—	—
Fat	3.00	2.61	2.61	2.62
Molasses	3.92	3.94	3.93	3.93
Sorghum wet distiller's grain	—	9.67	9.68	9.67
Supplement[2]	2.49	2.50	2.50	2.50
Analyzed composition				
DM, %	82.39	72.00	72.01	71.81
CP, %	12.95	13.25	14.01	14.68
ADF, %	9.89	12.27	12.10	12.06
EE, %	5.93	5.67	5.65	5.59
Ca, %	0.61	0.53	0.53	0.54
P, %	0.30	0.26	0.25	0.27
Ash, %	4.68	4.03	4.10	4.18
S, %	0.22	0.25	0.23	0.23
DIP, % of DM[1]	8.4	7.2	7.8	8.4

[1]Degraded intake protein (DIP) restored (by adding urea) relative to the control diet (standard 90% concentrate). The DIP values are calculated from NRC (1996) tabular values.

[2]Supplement contained (DM basis) 23.37% cottonseed meal; 0.500% Endox (Kemin Industries, Des Moines, IA); 42.11% limestone; 1.036% dicalcium phosphate; 8.000% potassium chloride; 3.559% magnesium oxide; 6.667% ammonium sulfate; 12.000% salt; 0.002% cobalt carbonate; 0.157% copper sulfate; 0.133% iron sulfate; 0.0025% ethylenediamine dihydroiodide; 0.267% manganese oxide; 0.100% selenium premix (0.2% Se); 0.845% zinc sulfate; 0.0079% vitamin A (1,000,000 IU/g); 0.126% vitamin E (500 IU/g); 0.675% Rumensin (176.4 mg/kg; Elanco Animal Health, Indianapolis, IN); and 0.45% Tylan (88.2 mg/kg; Elanco Animal Health). Concentrations in parentheses are expressed on a 90% DM basis.

implanted in the right ear with Revalor S (120 mg of trenbolone acetate + 24 mg of estradiol; Intervet) to start the experiment.

The 5 dietary treatments consisted of a standard SFC-based, 90% concentrate (DM basis) finishing diet formulated to contain 13.5% CP (**CON**), 3 finishing diets with 5, 10, or 15% (DM basis) SWDG (**S5%**, **S10%**, and **S15%**, respectively), and a finishing diet with 10% (DM basis) corn wet distiller's grains (**CWDG**) (**C10%**; Table 1).To eliminate any potential for excess dietary sulfur, a separate premix was used in diets containing distiller's grains in which ground corn replaced the ammonium sulfate used in the control premix (Table 1). The SWDG was obtained from a plant in New Mexico and was a composite (DM basis) of 47.1% sorghum centrifuge cake (directly from the centrifuge), 18.4% solubles (syrup), and 34.5% corn dried distiller's grains (**DDG**; DM basis). At the time the product was obtained for the experiment, the plant was storing WDG at the plant in plastic silage bags, and corn DDG was blended as a means of extending supplies and reaching target moisture content in the final product. The CWDG was obtained from a plant in Nebraska and was composed of approximately 65% centrifuge cake and 35% syrup (DM basis). Both SWDG and CWDG were each stored in a plastic silage bag for the duration of the experiment.

Estimates of the approximate quantity of unconsumed feed were made at 0700 to 0730 h daily, from which the daily feed allotment for each pen was determined. Bunk management was designed to leave little, if any, unconsumed feed (0 to 0.45 kg/pen) each day. At each weigh period, all feed bunks were cleaned and orts were weighed. Feed samples were taken directly from the feed bunks on a weekly basis, dried in a forced-air oven at 100°C for approximately 20 h, and ground in a Wiley mill to pass a 2-mm screen. Laboratory analyses (ADF, CP, DM ash, Ca, and P) were conducted using procedures described by AOAC (1990) and Galyean (1997).

Initial and final BW before slaughter were measured using an individual animal scale that was calibrated with certified weights before each use. Cattle were weighed every 28 d (pen basis) using a platform scale. Based on performance and visual appraisal, blocks of cattle were sent to a USDA-inspected slaughter facility in Plainview, TX, when approximately 60% of the block was expected to have sufficient finish to grade USDA Choice. Carcass data were obtained by personnel of the West Texas A&M University Beef Carcass Research Center. Carcass measurements obtained included hot carcass weight (**HCW**), LM area (**LMA**), marbling score of the split-lean surface at the 12th to 13th rib interface, percentage of KPH, fat thickness (**FT**), calculated USDA YG, and USDA QG.

Experiment 2

In October, 2005, 229 steers (primarily British × British and British × Continental crosses) were delivered to the Texas Tech University Burnett Center. Cattle were pro-

Table 3. Performance by cattle fed graded levels of sorghum wet distiller's grains and one level of wet corn distiller's grains (Exp. 1)

	Distiller's grains treatments[1]						Contrast[2]		
Item	0	S5%	S10%	S15%	C10%	SE	L	Q	C vs. S
Initial BW, kg	406.5	401.9	407.7	408.6	399.6	7.34	0.33	0.32	0.04
Final BW, kg	605.0	604.6	596.8	583.8	584.7	7.67	0.04	0.40	0.26
Adjusted final BW,[3] kg	605.8	607.1	594.9	579.3	585.2	8.02	0.009	0.25	0.35
ADG, kg									
d 0 to 28	1.83	1.87	1.73	1.61	1.72	0.08	0.03	0.33	0.94
d 0 to 56	1.68	1.73	1.59	1.32	1.49	0.07	0.001	0.03	0.30
d 0 to 84	1.66	1.71	1.55	1.40	1.51	0.05	0.001	0.06	0.53
d 0 to end[4]	1.50	1.54	1.43	1.32	1.40	0.05	0.01	0.13	0.63
Adjusted d 0 to end[3]	1.50	1.55	1.41	1.29	1.40	0.05	0.001	0.08	0.81
DMI, kg/d									
d 0 to 28	8.45	8.55	8.03	7.77	7.65	0.19	0.01	0.34	0.16
d 0 to 56	8.37	8.59	8.15	7.60	7.72	0.21	0.01	0.06	0.14
d 0 to 84	8.43	8.67	8.17	7.84	7.77	0.22	0.01	0.14	0.13
d 0 to end[4]	8.48	8.78	8.41	8.20	7.98	0.20	0.15	0.17	0.10
G:F									
d 0 to 28	0.217	0.218	0.215	0.206	0.224	0.01	0.30	0.51	0.40
d 0 to 56	0.201	0.201	0.195	0.174	0.193	0.01	0.001	0.04	0.80
d 0 to 84	0.197	0.198	0.190	0.179	0.194	0.01	0.002	0.15	0.53
d 0 to end[4]	0.177	0.175	0.170	0.160	0.175	0.01	0.01	0.34	0.42
Adjusted d 0 to end[3]	0.178	0.177	0.168	0.157	0.175	0.01	0.001	0.24	0.29

[1]Treatments were as follows: 0 = 90% concentrate control diet; S5% = 5% (DM basis) added sorghum wet distiller's grains; S10% = 10% (DM basis) added sorghum wet distiller's grains; S15% = 15% (DM basis) added sorghum wet distiller's grains; and C10% = 10% (DM basis) added wet corn distiller's grains.

[2]Observed significance level for orthogonal contrasts: L = linear contrast among sorghum wet distiller's grains levels; Q = quadratic contrast among sorghum wet distiller's grains levels; C vs. S = 10% wet corn distiller's grains vs. 10% sorghum wet distiller's grains.

[3]Adjusted BW was calculated from hot carcass weight divided by the average dressing percent (61.31%) of all the cattle, after which ADG and G:F values were recalculated using the adjusted BW.

[4]Cattle were fed an average of 133 d.

cessed as described for Exp. 1, and additionally given a 2-mL injection of a vitamin A and D3 solution (500,000 IU vitamin A and 75,000 IU vitamin D_3/mL; Phoenix Pharmaceuticals, St. Joseph, MO). Before starting the experiment, cattle were fed a 65% concentrate diet and Sudangrass hay, allowed free-choice access to water, and implanted in the right ear with Revalor-S (Intervet). Two-hundred steers (average BW = 369 ± 4.26 kg) were selected for the experiment, sorted to 10 blocks by BW, and assigned to 4 treatment groups within each block, resulting in 10 pens of 5 steers each per treatment.

The 4 dietary treatments consisted of a 90% concentrate SFC-based control (**CON**) diet (without SWDG) formulated to contain 13.5% CP and 8.4% DIP (DM basis), and 3 diets with 10% (DM basis) SWDG (Table 2). Among the 3 SWDG diets, one diet (**0DIP**) was formulated to have the same CP concentration as the CON diet (and therefore be potentially deficient in DIP); one diet had urea added to restore 50% of the difference in the DIP concentration between the 0DIP diet and CON; and one diet had urea added to restore 100% of the difference in the DIP concentration between the 0DIP diet and the CON treatment. Trace minerals, vitamins, and feed additives were added through a loose-meal premix (Table 2). Unlike Exp. 1, the premix composition of the premix was the same for the CON and SWDG diets. The SWDG was obtained from the same New Mexico plant as in Exp. 1, but the composition (DM basis), 63.4% sorghum centrifuge cake, 6.4% thin stillage, and 30.2% corn DDG, was slightly different than in Exp. 1.

Overall cattle management, bunk and feeding management, and weighing processes followed the same procedures as in Exp. 1. Feed samples were taken directly from the mixer-delivery unit on a weekly basis, dried at 100°C in a forced-air oven for approximately 20 h, and ground in a Wiley mill to pass a 2-mm screen. As in Exp. 1, SWDG was stored in a plastic si-

Table 4. Carcass characteristics of steers fed graded levels of sorghum wet distiller's grains and one level of corn wet distiller's grain (Exp. 1)

	Distiller's grains treatments[1]						Contrast[2]		
Item	0	S5%	S10%	S15%	C10%	SE	L	Q	C vs. S
Hot carcass weight, kg	371.4	372.2	364.8	355.1	358.8	4.92	0.009	0.25	0.35
Dressing percent	61.40	61.59	61.14	60.97	61.40	0.36	0.28	0.63	0.60
LM area, cm^2	94.26	89.77	87.23	85.70	90.30	1.70	0.001	0.39	0.21
Fat thickness, cm	1.11	1.22	1.28	1.17	0.97	0.09	0.55	0.23	0.02
Yield grade	2.41	2.75	2.88	2.76	2.36	0.15	0.09	0.14	0.02
Marbling score[3]	411.5	441.6	428.8	438.5	412.4	14.81	0.27	0.46	0.40
USDA Choice, %	45.63	60.63	57.50	55.00	50.00	—	0.53	0.28	0.58

[1]Treatments were as follows: 0 = 90% concentrate control diet; S5% = 5% (DM basis) added sorghum wet distiller's grains; S10% = 10% (DM basis) added sorghum wet distiller's grains; S15% = 15% (DM basis) added sorghum wet distiller's grains; and C10% = 10% (DM basis) added wet corn distiller's grains.

[2]Observed significance level for orthogonal contrasts: L = linear contrast among sorghum wet distiller's grains levels; Q = quadratic contrast among sorghum wet distiller's grains levels; C vs. S = 10% wet corn distiller's grains vs. 10% sorghum wet distiller's grains.

[3]Marbling score: 300 = slight; 400 = small.

lage bag, and samples of SWDG were collected weekly from the bag and frozen. Laboratory analyses (ADF, CP, DM ash, S, Ca, P, and ether extract) were performed according to methods described in AOAC (1990) and Galyean (1997), with 3 exceptions: 1) samples of SWDG used for ADF were not dried or ground before analysis; 2) a procedure was used for ether extract (**EE**) in which samples were first extracted with water, followed by treatment with petroleum ether to extract lipids; and 3) the sulfur content was determined by a commercial laboratory (SDK Laboratories, Hutchinson, KS). For the EE procedure, the first step was to ensure that water-soluble components of the feed were not lost during extraction with petroleum ether. This was accomplished by mixing diet samples with 100 mL of warm water and filtering through Whatman No. 541 paper (Whatman International Ltd., Maidstone, UK) before ether extraction. Dry weights were measured before and after this step to determine the percentage of water-soluble DM. Duplicate 2-g samples of the residue after water extraction were weighed and placed in a 250-mL Erlenmeyer flask fitted with a ground-glass stopper. One hundred milliliters of petroleum ether was added to the flask, and the stopper was secured. The flasks were placed in an oscillating shaker (Environ-Shaker, Lab-Line Industries, Melrose Park, IL) for 2 h at 175 rpm. Flask contents were then filtered using a gravity-flow funnel through previously dried filter paper (Whatman No. 541) and rinsed with petroleum ether. The residue was dried at 100°C for 24 h, weighed, and the EE was calculated from the loss in weight of the dry residue, adjusted for the loss of water soluble DM.

Blocks of cattle were shipped to the USDA-inspected slaughter facility in Plainview, TX when approximately 60% were visually appraised to have accumulated sufficient body fat to grade USDA Choice. Carcass characteristics were obtained by personnel of the Texas Tech University Meat Laboratory and included HCW, LMA, marbling score, FT, YG, and USDA QG.

Statistical Analyses

Data from both experiments were analyzed as randomized complete block designs using the MIXED procedure of SAS (SAS Institute Inc., Cary NC). Variables included were BW, DMI, ADG, G:F, HCW, carcass-adjusted variables (determined using carcass-adjusted final BW, which was calculated as HCW divided by the average dressing percent), and other nondiscrete carcass characteristics. Pen was the experimental unit for all analyses. Model statements included the fixed effect of treatment and the random effect of block. Data for animals not completing the trial because of sickness, injury, or death were removed before analyses (3 steers in Exp. 1 and none in Exp. 2). In Exp. 1, specific contrasts were used to test the following treatment responses: 1) the response to graded levels of SWDG (linear, quadratic, and cubic); and 2) the comparison of the S10% vs. C10% treatments. Cubic effects of SWDG level were not significant ($P > 0.10$) and are not reported. In Exp. 2, the following specific contrasts were used to test the treatment responses: 1) CON vs. average of all SWDG diets; 2) linear effect of restored level of DIP; and 3) quadratic effect of restored level of

Table 5. Effects of degraded intake protein concentration in diets containing 10% sorghum wet distiller's grains (DM basis) on BW and performance by finishing beef steers (Exp. 2)

	DIP restored,[1] %					Contrast[2]		
Item	Control	0	50	100	SE[3]	CON	L	Q
Initial BW, kg	370.4	368.7	367.7	369.1	9.41	0.25	0.85	0.48
Final BW, kg	605.3	596.2	586.7	582.6	10.21	0.03	0.13	0.73
Adjusted final BW, kg	607.4	593.2	588.6	582.1	11.36	0.03	0.29	0.92
ADG, kg								
d 0 to 35	2.38	2.26	2.19	2.23	0.074	0.03	0.74	0.51
d 0 to 70	2.16	2.06	1.97	2.01	0.063	0.03	0.51	0.37
d 0 to 105	1.94	1.86	1.78	1.78	0.059	0.03	0.23	0.58
d 0 to end	1.72	1.68	1.61	1.57	0.053	0.04	0.08	0.86
Adjusted d 0 to end[3]	1.74	1.66	1.63	1.56	0.063	0.04	0.21	0.77
DMI, kg/d								
d 0 to 35	9.26	9.07	8.92	8.96	0.155	0.01	0.37	0.37
d 0 to 70	9.42	9.25	9.04	8.97	0.198	0.04	0.14	0.66
d 0 to 105	9.37	9.32	9.05	8.87	0.219	0.09	0.03	0.79
d 0 to end[3]	9.24	9.25	8.99	8.72	0.224	0.14	0.02	0.99
G:F								
d 0 to 35	0.258	0.248	0.246	0.249	0.01	0.11	0.96	0.66
d 0 to 70	0.229	0.222	0.218	0.224	0.01	0.06	0.75	0.25
d 0 to 105	0.207	0.199	0.197	0.200	0.01	0.04	0.85	0.44
d 0 to end	0.186	0.181	0.179	0.180	0.01	0.05	0.67	0.69
Adjusted d 0 to end[3]	0.188	0.179	0.180	0.179	0.01	0.07	0.96	0.78

[1]Degraded intake protein restored (by adding urea) relative to the control diet (standard steam-flaked corn-based 90% concentrate). The control, 0, 50, and 100% DIP-restored diets had calculated (NRC, 1996) DIP concentrations of 8.4, 7.2, 7.8, and 8.4% DIP (DM basis), respectively.

[2]Observed significance level for orthogonal contrasts: CON = control vs. the average of all sorghum wet distiller's grain diets; L = linear effect of level of DIP restored; and Q = quadratic effect of level of DIP restored.

[3]Adjusted final BW was calculated as hot carcass weight divided by the average dressing percent (62.05%). Carcass-adjusted ADG was calculated as adjusted final BW minus initial BW divided by days on feed. Carcass-adjusted G:F was the ratio of carcass-adjusted ADG to daily DMI. Days on feed varied from 120 (8 pens) to 132 (12 pens) and 146 (20 pens).

DIP. In both experiments, the GLIMMIX procedure of SAS was used to analyze the proportion of cattle in each pen grading USDA Choice or greater, with the same model used for performance data. For all statistical analyses, P values less than 0.10 were considered significant.

RESULTS AND DISCUSSION

Experiment 1

Chemical composition of the experimental diets was similar to that expected from formulation (Table 1), except that CP was less than anticipated. Final unshrunk BW (Table 3) decreased linearly ($P = 0.04$) with increasing level of SWDG. Similarly, ADG decreased linearly during all periods in the study ($P \leq 0.03$) as level of SWDG increased. No differences between C10% and S10% for ADG were noted during any period of the trial ($P \geq 0.30$). Average daily gain ($P < 0.01$) also decreased linearly with increasing level of SWDG in the diet when adjusted to a constant dressing percent (61.31%), but adjusted ADG did not differ ($P = 0.81$) between the S10% and C10% treatments.

No differences ($P = 0.15$) were observed for overall DMI with increasing levels of SWDG; however, increasing the level of SWDG decreased DMI linearly ($P = 0.01$) from d 0 to 28, d 0 to 56, and d 0 to 84. Similarly, Larson et al. (1993) found decreased DMI with increased amounts of CWDG in the diet. Moreover, Ham et al. (1994) noted that DMI was less by cattle fed CWDG than corn DDG, suggesting that intake decreased as DM content of the diet decreased. Trenkle (1997a) reported this same decrease in DMI when feeding elevated amounts of CWDG; however, Lodge et al. (1997) observed no significant change in DMI when feeding SWDG compared with a dry-rolled corn (**DRC**) control diet. Al-Suwaiegh et al. (2002) compared diets containing DRC (control), CWDG replacing 30% (DM basis) of DRC, and SWDG replacing 30% (DM basis) of DRC. Results indi-

Table 6. Effects of degraded intake protein concentration in diets containing 10% sorghum wet distiller's grains (DM basis) on carcass characteristics of finishing beef steers (Exp. 2)

	DIP restored,[1] %					Contrast[2]		
Item	Control	0	50	100	SE	CON	L	Q
Hot carcass weight, kg	376.9	368.1	365.2	361.2	7.05	0.03	0.29	0.92
Dressing percent	62.24	61.74	62.24	61.98	0.299	0.46	0.56	0.29
LM area, cm^2	89.75	89.59	89.07	89.30	2.113	0.80	0.89	0.83
Fat thickness, cm	1.21	1.12	1.06	0.99	0.053	0.02	0.08	0.99
Yield grade	3.30	3.09	3.01	2.95	0.099	0.01	0.24	0.94
Marbling score[3]	421.6	438.8	412.4	418.1	15.09	0.93	0.33	0.38
USDA Choice, %	54.00	58.00	54.00	51.50	—	0.94	0.42	0.91

[1]Degraded intake protein restored (by adding urea) relative to the control diet (standard steam-flaked corn-based 90% concentrate). The control, 0, 50, and 100% DIP-restored diets had calculated (NRC, 1996) DIP concentrations of 8.4, 7.2, 7.8, and 8.4% DIP (DM basis), respectively.

[2]Observed significance level for orthogonal contrasts: CON = control vs. the average of all sorghum wet distiller's grain diets; L = linear effect of level of DIP restored; and Q = quadratic effect of level of DIP restored.

[3]Marbling score: 300 = slight; 400 = small.

cated that DMI with either source of distiller's grains (**DG**) was similar to that by cattle fed the control diet; however, DMI between WDG sources was slightly greater for the SWDG diet, but ADG and G:F did not differ between SWDG and CWDG diets. In contrast to our results, recent findings indicated a linear increase in DMI as dietary level of SWDG increased in finishing diets containing SFC (Drouillard et al., 2005). In the current study, when C10% was compared with S10%, there was a tendency (*P* = 0.10) for greater DMI by cattle fed S10%. It is unclear why this occurred; however, the CWDG was finer in texture, and this physical difference might have contributed to the decreased DMI. A finer texture (smaller particle size) might result in more rapid fermentation of CWDG vs. SWDG, thereby contributing to a lower DMI with CWDG.

Because overall DMI of diets containing DG in the current study was similar to the control diet but ADG differed, G:F was different for d 0 to 56 and d 0 to 84 (*P* < 0.01), with cattle consuming higher levels of SWDG gaining less efficiently. Moreover, a linear decrease in G:F for the entire feeding period (*P* = 0.01) was observed as the level of SWDG increased in the diet. In contrast, Drouillard et al. (2005) reported a quadratic response in G:F when adding SWDG to SFC-based diets, with a maximum response in G:F between 8 and 16% SWDG. In our study, no differences were observed in overall G:F between S10% and C10% treatments (*P* = 0.42). These results contrast previous data showing improved feed efficiency in cattle fed CWDG in DRC-based diets (Larson et al., 1993; Ham et al., 1994). Larson et al. (1993) reported that both ADG and G:F increased as level of CWDG increased in DRC diets. Likewise, Ham et al. (1994) reported greater ADG and improved feed efficiency for cattle fed DRC diets supplemented with either wet or dry corn DG. Trenkle (1997a,b) also showed that ADG was greater by cattle fed CWDG than by those fed a DRC control diet. Lodge et al. (1997), however, reported no differences in ADG and G:F for cattle fed SWDG compared with those fed a basal DRC control diet. Because most of these previous studies used diets based on DRC, it may be invalid to compare those findings with the present results, which involved the feeding of diets containing SFC. Moreover, results from previous studies have shown considerable variability in terms of cattle response to the feeding of DG.

The decreased ADG during the feeding period with increasing level of SWDG resulted in a linear decrease in HCW (Table 4; *P* < 0.01) and in LMA (*P* < 0.01). The linear decrease in these 2 variables, coupled with slight increases in FT, most likely resulted in the tendency for a linear (*P* = 0.09) increase in YG noted with increasing level of SWDG. There were no significant linear or quadratic effects (*P* > 0.10) in FT, KPH, marbling scores, cattle grading USDA Choice or greater, or dressing percent. Larson et al. (1993) reported no differences among control and CWDG treatments for carcass characteristics in an experiment with yearling cattle. In contrast, in a calf finishing experiment (Larson et al., 1993), quality grade increased as level of WDG increased. Ham et al. (1994) found similar results to the Larson et al. (1993) yearling finishing trial, whereas Trenkle (1997a) showed that cattle fed lower levels of CWDG (20%, DM basis) tended to have larger LMA and greater FT than those fed higher levels (40%, DM basis).

Experiment 2

All diet analyses (Table 2) were in general agreement with expectations based on formulated values. The ADF content was greater in diets containing SWDG, reflecting the fact that SWDG contained 38.4% ADF, and it replaced dietary ingredients such as corn and cottonseed meal with much lower ADF. The EE values were consistent among diets containing SWDG, with slightly lower values than CON.

Final unshrunk BW was greater for steers fed CON than for the average of the SWDG diets ($P = 0.03$). This advantage in BW for CON also was significant ($P = 0.03$) when adjusted BW was calculated by dividing HCW by a constant dressing percent. During the entire study, ADG was superior by cattle fed CON compared with the mean of the 3 SWDG diets based either on unshrunk live ($P = 0.04$) or on carcass-adjusted BW ($P = 0.04$). There was a linear decrease in overall ADG (live BW basis) as the level of DIP restored increased ($P = 0.08$), but adjusted ADG was not affected ($P = 0.21$ for the linear contrast) by the level of DIP restored. Cattle fed CON consumed more DM (Table 5) than the average of all SWDG diets for d 0 to 35, d 0 to 70, and d 0 to 105 ($P = 0.01$, 0.04, and 0.09, respectively). Despite the fact that this numerical advantage in DMI for CON continued throughout the entire trial, it did not differ for the overall feeding period (d 0 to end; $P = 0.14$). Dry matter intake decreased linearly with increasing levels of DIP for d 0 to 105 ($P = 0.03$) and d 0 to end ($P = 0.02$). Reasons for the linear decrease in DMI as the level of DIP restored was increased are unclear, and this response was unexpected. For G:F, CON values were greater than the average of all SWDG diets throughout the entire trial, whether expressed on a live BW basis ($P = 0.05$) or on a carcass-adjusted basis ($P = 0.07$).

As expected from BW and ADG data, HCW (Table 6) was greater for cattle fed the CON diet compared with the mean of the 3 SWDG diets ($P = 0.03$). There was no difference in dressing percent ($P = 0.46$) among treatments, but the carcasses of steers fed CON diet had greater FT ($P = 0.02$) and USDA YG ($P = 0.01$), presumably reflecting the greater HCW of these cattle and a greater degree of physiological maturity at slaughter than for the lighter, slower gaining cattle fed the SWDG diets. Despite differences in external fat cover, however, the percentage of carcasses that graded USDA Choice did not differ ($P > 0.10$) among treatments.

Russell et al. (1992) suggested that starch fermentation is an accurate predictor of DIP requirements, which suggests that increased starch availability (SFC-based diets) may increase the DIP requirement compared with diets containing starch of lower availability (DRC-based diets). Nonetheless, a need for greater DIP concentrations with SFC-based diets that include SWDG is inconsistent with the findings of the current study, as performance was generally decreased as level of DIP restored increased in these SFC-based diets containing SWDG. Data from Vander Pol et al. (2005) indicated that DRC-based diets containing sufficient metabolizable protein but deficient in DIP may still be capable of providing sufficient protein to maintain performance, presumably via N recycling. In experiments conducted with forage-fed cattle, Klopfenstein and Adams (2005) did not observe responses to added urea in DRC-based diets containing WDG, which also might suggest that N recycling was sufficient to meet DIP requirements of the ruminal microorganisms. It is possible that the metabolizable protein balance remained fairly constant in all diets in the current study; therefore, a lack of a response to added DIP could be explained by N recycling, but the linear decrease in ADG and G:F with increasing DIP is difficult to explain.

The reason for inferior performance by steers fed the SWDG diets in these 2 experiments is not clear. The SWDG diets contained larger percentages of ADF, which may have diluted the energy concentration of the diets. In Exp. 2, the SWDG diets also had slightly lower values for EE than the control diet, which could have had a slight adverse effect by diluting energy concentrations. Generally, however, one might expect these factors to result in greater DMI by cattle fed the SWDG diets, reflecting an effort by the cattle to compensate for dilution effects. Why these factors seem to have worked in a manner opposite to the expected compensatory response is unclear and needs further study.

IMPLICATIONS

Our data suggest decreased performance and carcass value with increasing levels of SWDG alone or in combination with increasing levels of DIP when added to a diet based on SFC. At 10% of the dietary DM, corn and sorghum WDG resulted in similar ADG and G:F. Overall, data from these 2 experiments are not consistent with results from previous research. Because of these contradictory findings, additional research is needed to determine the reason for the absence of a response when feeding these coproducts and the negative reaction to increasing DIP concentration.

ACKNOWLEDGMENTS

The authors thank Cactus Feeders, Ltd., Amarillo, TX for providing the cattle used in the experiment, Abengoa Bioenergy (Portales, NM) for providing distiller's grains, and DSM Nutritional Products (Belvidere, NJ), Elanco Animal Health (Greenfield, IN), Fort Dodge Animal

Health (Overland Park, KS), Intervet (Millsboro, DE), and Kemin Industries (Des Moines, IA) for supplying various products used during the experiment. The authors also thank K. Robinson and R. Rocha for technical support in animal care and feeding.

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